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E3.pt – An E3 PortableDyme Model for Portugal

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Abstract: E3 models are environmentally extended economic models. They are extensively used for impact assessment of energy, climate and resource policies at national and international level. E3 models have proven to be suitable tools for quantifying effects on the economy, environment and energy system. Usually, the structure and documentation of such models are only accessible by the model builders. They are facing the allegation to be a "black box" meaning that only their creators are able to operate and fully understand the model system. Decision makers are often only engaged at the end of the model building process to discuss the outcome of the model. Participatory modeling is rather limited. PortableDyme is a complete model building framework: it includes all tools (data processing routines, regression software, evaluation tools) that are necessary for building and applying a sophisticated E3 model. Additionally, it comes with a fully documented, extensible, pre-structured model which allows for engaging policy makers and field experts at each stage of the model building process. The framework is a "white box": It contains the full source code for both the model runtime and the generic model. E3.pt is an adoption of the generic economic PortableDyme model for Portugal. It covers the economy, environment and the energy system (so-called E3 model).

***Keywords**:* PortableDyme model building framework; integrated modeling approach; participatory modeling; scenario analysis.

1 INTRODUCTION TO THE PORTABLEDYME MODEL BUILDING FRAMEWORK

Building a sophisticated macroeconomic multisectoral model, especially one that also reflects the interdependencies between economy, environment and emissions (E3), is by no means a simple task. Model builders not only have to have in-depth knowledge i.a. of macroeconomic theory and energy economics but also have to be familiar with information and communication technology (ICT) topics such as data processing, programming and usage of various software packages for data analysis and visualization. In most cases, such a model can only be maintained and operated by the model builders themselves. This is the main reason why stakeholders and field experts often consider computer models as “black boxes”: The inner structure of the model is either not documented or not published at all. Thus, results are questionable and can hardly be trusted.

The PortableDyme (PD) model building framework addresses these issues by providing an all-in-one package which not only contains a complete set of essential model building software but also comes with a well-documented basic macroeconomic model. Additionally, the package provides tools for performing scenario analysis which may be used by both model builders and end-users who are familiar with E3 background.

The following paragraphs give an overview of the core features and building blocks of the PD framework.

PD is portable. The framework is self-contained, runs on every Microsoft Windows computer and may be copied between computers and storage devices without installation.

PD is free software. Each software component has been carefully selected to ensure that the package may be used free of charge. The only prerequisite is a working copy of Microsoft Excel and a free membership of the INFORUM group (http://www.inforum.umd.edu).

Software components. PD is built on top of the INFORUM set of programs which has been developed at the University of Maryland, USA, more than 20 years ago to build sophisticated macroeconomic multisectoral models. Amongst others, the INFORUM software provides the programming library

INTERDYME which efficiently deals with the core building blocks of a model – time series, matrix algebra and equations (INFORUM 2008). The software G7 is used for data processing and regression analysis (INFORUM 2011). The free C++ compiler ensures both rapid execution and scalability of a model. The package is also equipped with a user-friendly editor and a project template reflecting the different steps of the model building process (Figure 1).

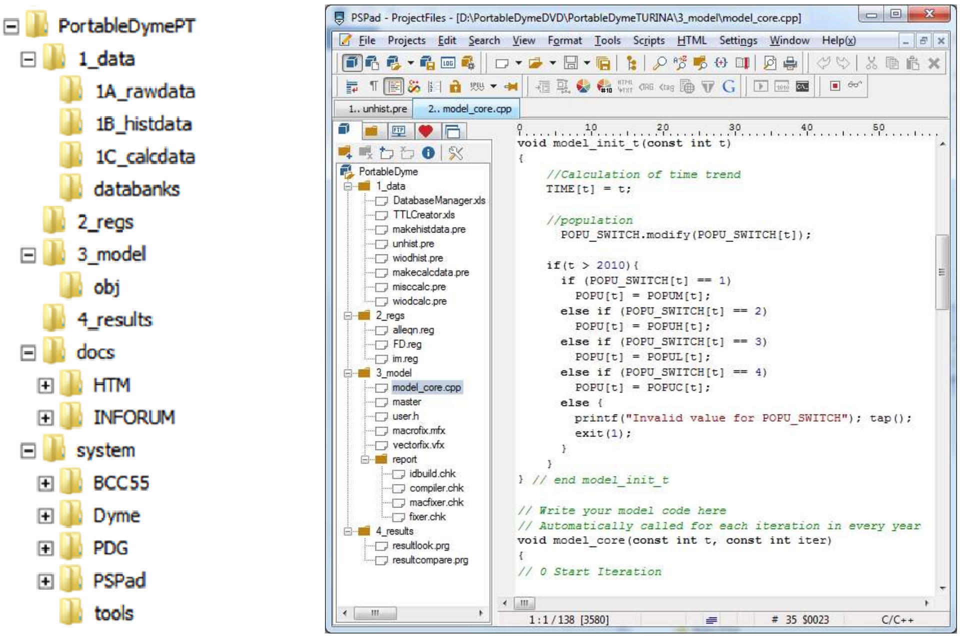

Figure 1. Structure of PortableDyme Models.

For each of the main steps

1. Building of the historical database (1_data)
2. Regression analysis (2_regs)
3. Core model building (3_model)
4. Scenario analysis (4_results)

the PD framework contains source code and script files which may be tailored by the model builder. A detailed discussion of the folder contents is beyond the scope of this paper (Großmann et al. 2013, 2013a).

No "black box". The framework contains the full source code for its data processing, model execution and scenario analysis statements. Thus, the model can be fully verified, tailored and/or extended to meet specific requirements.

Scenario analysis. One of the biggest issues with many existing models is that they can only be operated by their creators, mainly because of the inherent complexity and/or missing documentation. Therefore, performing scenario analysis is often impossible for field experts or stakeholders. To overcome this hurdle, a PD model provides a mechanism called “fixes”: A scenario is defined as a set of adjustments (“fixes”) which may be applied to model variables that are given by either a behavioral equation or exogenously (INFORUM 2009). The model picks up these adjustments at runtime and overwrites the values which were internally calculated by the model. The effects of the adjustments can later be analyzed by comparing the outcome of different scenarios. Since scenarios are defined in an external file, it is not necessary to change the source code of the model. Thus, scenario analysis may be carried out by users who are familiar with the core mechanisms of the model but do not fully understand the (technical) details of the model.

Visualization. A sophisticated model can easily contain several thousand variables. Although PD provides access to each variable in the database, only a few variables are relevant to evaluate a certain policy. PD models can be connected to Microsoft Excel to extract relevant data from the database and to visualize this data in customized spreadsheets and/or graphs. Even with complex scenarios this process only takes a few seconds.

2 E3.PT: ECONOMY – ENVIRONMENT – ENERGY MODEL FOR PORTUGAL

2.1 Overview

E3 models provide an integrated view on the economy, environment and emissions as well as the interactions between them. Such models are widely used to analyze pathways into a sustainable future especially in the context of energy and climate policies (Ortiz, Markandya 2009, GWS et al. 2014, Barker et al. 2011). "Sustainable" is not only interpreted with regard to energy consumption and emissions. The impacts on welfare and employment should be considered as well to recognize unintended and undesirably developments. In contrast to partial models, the all-in-one modeling approach allows for simultaneous calculation of impacts on the three Es.

Models assessing sustainable policy strategies and interventions usually differ in regional coverage (national, multi-regional, global), level of detail (consideration of single technologies, industries or the whole macro-economy) and economic behavior as well as assumptions on technological progress. Well-known E3 models are the General Equilibrium Model GEM-E3 for the European Union and the global Computable General Equilibrium (CGE) model GTAP-E as well as the global macro-econometric models E3ME and GINFORS (Capros et al. 2013, Truong et al. 2007, Cambridge Econometrics 2014, Meyer et al. 2013). Apart from multi-regional E3 models, many national E3 models exist (e.g. Lutz et al. 2014, Stocker et al. 2011).

E3.pt is a new E3 model for Portugal and can be classified as a national macro-econometric input-output (IO) model (West 1995). Its key characteristics are as follows:

Comprehensive and integrated modeling: E3.pt is a comprehensive, integrated model showing the economy, environment and the energy system as well as their interrelations. Most variables are modeled endogenously and are dependent on each other. Only a few variables are given exogenously such as population which is taken from Eurostat forecasts.

The construction of the economic model follows the INFORUM philosophy (Almon 1991, 2014). Economic growth is determined at the industry level by modeling quantity and price relationships (bottom-up-approach). "Macro" indicators such as GDP and its components like consumptions and investments and employment are then derived by summing up industry-specific results. Inter-industry dependencies are explicitly considered by following the Leontief approach (Leontief 1986).

Linking the IO approach and national accounts allows for showing the complete economic circuit and the monetary flows from production to consumption as well as the interaction of economic actors (total integration).

The INFORUM approach allows for detailed analysis of economic consequences on industries and economic actors. Winners and losers of policy measures can be easily identified.

Econometric specification. e3.pt is empirically specified by using econometric methods which are the basis for dynamic models. In contrast to static models they account for time-dependency and describe the evolution of agents' behavior over time. Using econometric methods allows for imperfect markets and bounded rationality. Therefore, e3.pt is not limited to restrictive assumptions that are common to CGE models.

Forecasting and scenario analysis. Econometric IO models are suitable for forecasting and scenario analysis. The most basic forecast assumes that past behavior is also effective in the future (business as usual, BAU). Scenario analysis is a method to analyze the impact ("what if") of policy measures on future developments. A scenario consists of a set of consistent assumptions which are fed into the model. The "new" forecast is then calculated within a few seconds. Comparing two scenarios reveals differences that can be interpreted as reactions to the impulses induced by certain policy measures.

Modular extensible architecture. Due to its open structure, the e3.pt model can be further expanded to client or researcher needs (e.g. regional modelling, social aspects).

Transparency. PD models are no "black boxes". All programming statements, model equations, assumptions and data are accessible and documented.

Participatory modeling approach. Due to the transparent, fully documented structure of the PD model, stakeholders and experts can participate in each step of the model building process. The model building steps may have to be repeated under certain conditions, e.g. availability of updated or additional data.

This participatory modeling approach is already applied in projects dealing with sustainable developments and strategies e.g. in Germany and Russia. PANTA RHEI – the environmentally extended macroeconomic model for Germany – is applied at the Federal Environmental Agency (UBA) and the Federal Ministry for Economic Affairs and Energy (BMWI) for own scenario analysis. The model was applied for i.a. calculating the macroeconomic effects of the German Energy Transition. The Russian model e3.ru was developed for the Russian Ministry of Economy and applied to evaluate economic and environmental effects of sustainable policy measures (Großmann et al. 2011).

2.2 Model building steps and the participation of stakeholders

Database. The base of every quantitative model is data which should come from official sources (national and international statistical offices, e.g. Eurostat). The selection of data depends on the aim of the modeling exercise. Here, the model should be used for evaluating sustainable strategies and their impacts on the 3E's. Thus, economic, energy and environmental and some demographic data have to be incorporated into the e3.pt model database. The most important variables are IO tables, GDP and its components (in real and nominal values), the energy balance and energy prices as well as emissions. Sometimes, stakeholders may provide unofficial data which is more accurate or recent.

Regressions. The availability of historical data is the most important prerequisite for regressions. Regression analysis is done with the G7 software which provides different estimation procedures such as Ordinary Least Squares (INFORUM 2011). Regression results (parameters / coefficients) show the direction and magnitude of the relation between the dependent and independent variable(s). In contrast, variables that are part of a definition have a fixed relation to each other.

In e3.pt, most of the final demand components are estimated as well as prices and labor market variables such as employment and wages (Meade 2014). In the energy module, final energy consumption by sectors (households, commerce and industries) is estimated by production and an average energy price within a sector (Lutz et al. 2011). If relevant, a time trend for technological progress is included. The strength of the relation between dependent and independent variables is hinged on the energy efficiency. Energy prices are dependent on world market prices for oil, gas and coal plus energy taxes and other relevant price components.

It has to be pointed out although a regression may produce excellent results measured with statistical tests, its integration into a structural model may have negative side-effects causing instability to the model. It is important to incorporate parameters with reasonable signs and magnitudes. Furthermore, parameters show past relations. They are not necessarily valid in the future. Field experts may help to justify forecasted developments.

Model Core. The main task of this model building step is to create the model structure by putting the set of equations together. Most equations – both regressions and definitions – are not independent but interrelated to other equations. Right-hand side variables of one equation are calculated as left-hand side variables within another equation. Sometimes, related equations are not even part of the same module. The model builder has to carefully define the sequence in which the equations have to be calculated.

Figure 2 shows a simplified scheme of interrelation of model variables. The economic module includes supply (e.g. energy and labor) and demand side elements (e.g. consumption, investment) as well as quantities and prices at industry level. Final demand components serve as input for the Leontief Inverse to calculate output and value added at industry level (bottom-up approach). Consumption and investments are estimated. Exports are given exogenously by a bilateral trade model that links the most important countries and regions of the world (Bardazzi, Ghezzi 2015).

Adding up all industry information results in macro variables that correspond to national account variables such as consumption and investment. Other variables calculated within the System of National Accounts (SNA) serve as input for regressions (e.g. disposable income in the econometric equations for private consumption).

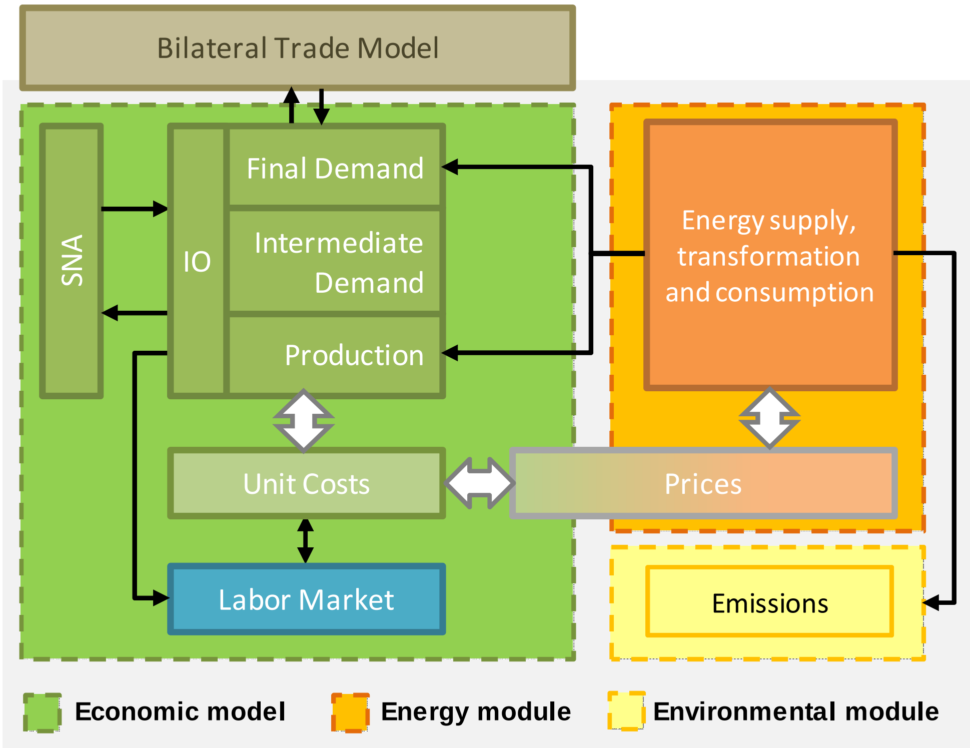

Figure 2. Simplified structure of the model e3.pt.

The economic model may follow an economic theory chosen by the model builders and/or stakeholders. PD models are not restricted to a certain modeling approach like e.g. GTAP models that are CGE models (Hertel 1997).
In the case of e3.pt, the modeling approach is a combination of elements of different theories. The model is demand side driven (Keynes' approach) but includes supply and price elements to account for supply constraints. Therefore, unemployment and overproduction may occur. Prices are not set as an equilibrium price. It is assumed that firms set their prices according to their material, labor, energy etc. costs and prices of their competitors (mark-up pricing).
The energy module describes the relations within the energy sector in more detail than the economic model. It depicts the energy demand, supply and transformation by different fossil fuels and renewables as stated in the energy balance. Primary energy inputs for power generation as well as heat generation by different energy producing technologies (combined heat and power plants, power plants, photovoltaic etc.) are captured. Efficiency factors are modeled and can be adjusted according to input from energy experts.
The energy module is embedded into the economic model. Economic growth and energy prices influence energy demand by industries. The detailed information generated within the energy module is fed back into the economic model.
At this stage of model expansion, the environmental module comprises the energy-related CO_2 emissions. Reductions in the use of fossil fuels caused by deployment of renewable energy or increased energy efficiency can be seen in CO_2 savings. In contrast to the energy module, the environmental module has only reporting characteristics and no feed-back effects into the economic model.
The modularization has the advantage that each module can be developed by specialists and later incorporated into the complete model. Especially in the field of energy technologies the involvement of expert knowledge is highly important. Even energy system models – that model the energy system from plant side and with much more detail – can be integrated due to the modularization and open structure of PD models.
All model equations are solved year by year and a forecast is usually 10 to 50 years. Due to many feedback linkages the model has no explicit solution and solves all model equations iteratively. The iteration process is ended once a given criterion is fulfilled.

Scenarios. The inherent uncertainty of the future makes it impossible to forecast one "real" prospective development. Scenario analysis is a method to handle uncertainty and to carry out "what if"-analysis especially to analyze the impacts of policy measures before implementation. The engagement of stakeholders in scenario design and evaluation of scenario results is widely used (Stocker et al. 2014, Reed et al. 2013). First, scenario assumptions and the expected consequences are discussed. After running the model with the new assumptions, possible unintended impacts that become visible by analyzing model results are evaluated. The differences in results illustrate the impacts of the initial changes at a specific point in time and over time (Figure 3). They can be interpreted as responses to the "shock" induced by certain policies. Pros, cons and trade-offs of scenarios are turned out and the best solution can be identified. Policy and decision makers are usually the addressees of these results and derived recommendations. It is obvious that an early involvement of stakeholders increases the acceptance of model outcome and avoids implausible results.

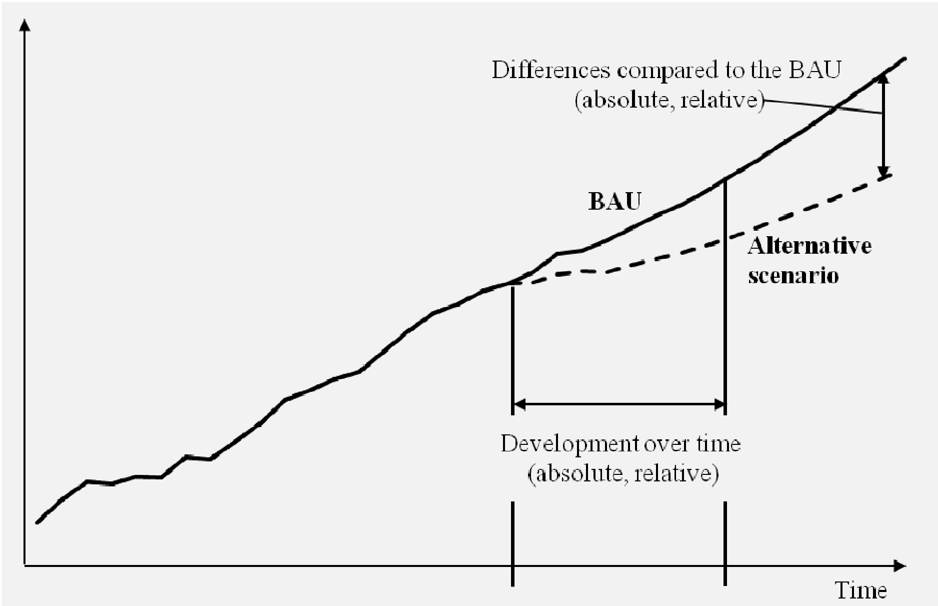

Figure 3. Comparing scenarios.

3 CONCLUSIONS

The PD model building framework has been successfully used in the past for capacity building in different countries. E3.pt is the first E3 model based on this framework. It shares the same features which makes it a powerful tool for stakeholder engagement in the fields of e.g. industry analysis and CO_2 abatement strategies such as improving energy efficiency or deployment of renewable energy. It is well-suited for answering "what if" questions. The outcome of different policies may be analyzed and discussed with stakeholders and field experts to find the most suitable solution.

Due to its open and well-documented structure it may be easily adopted to more specific questions such as labor market policies, social inequality analysis or regional analysis.

A more generalized version of the e3.pt model will become an integral part of the international bilateral trade system (BTM) of the INFORUM group (Bardazzi, Ghezzi 2015).

Furthermore, the use of Eurostat statistical data allows for easy adoption of the model to other EU countries.

The authors hope that PortableDyme helps other model builders to better understand the essential tasks of modeling, to build their own PD models and to improve interactions with stakeholders.

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